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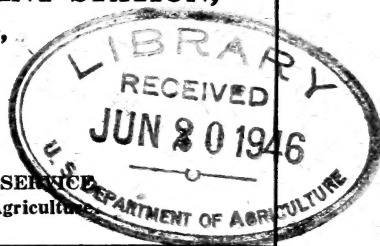
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PORTO RICO AGRICULTURAL EXPERIMENT STATION,

**D. W. MAY, Agronomist in Charge,
Mayaguez, P. R.**

BULLETIN No. 27.

Under the supervision of the STATES RELATIONS SERVICE
Office of Experiment Stations, U. S. Department of Agriculture



YAM CULTURE IN PORTO RICO.

BY

C. F. KINMAN, Horticulturist.



Issued May 24, 1921.



**WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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[Under the supervision of A. C. TRUE, Director, States Relations Service, United States Department of Agriculture.]

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YAM CULTURE IN PORTO RICO.

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THE YAM AS A FOOD CROP IN PORTO RICO.

The yam is one of the important foods of Porto Rico, and among the root crops is second in this respect only to the yautia. The quantity consumed is far greater than of either the Irish potato or the sweet potato. It is found in nearly every family garden in Porto Rico, because it is well adapted to most soils of the island and is almost entirely free from destructive insect pests and plant diseases. Notwithstanding its importance and wide local distribution, very little has been written regarding its culture, at least so far as this has a bearing on the agricultural conditions of Porto Rico. Planters are so sure of obtaining a fair yield that they have developed to a large degree a tendency to be content with a moderate crop from a moderate outlay. Practically the entire production is for home consumption.

With the great increase in price of all food products, the yam, which is still among the least expensive of the food crops, is more in demand than formerly. Yet, despite the fact that high prices for foods have prevailed and the local consumption of the yam has been stimulated, its use in other countries has increased but little. If properly handled, however, it might be shipped to other markets with little fear of loss by deterioration. In the continental United States the yam is rarely purchased by any other than people from the Tropics, and it is still practically unknown. In the Southern States the name "yam" is commonly applied to a certain type of sweet potato, which, however, is a different plant. The high food value of the yam, due mainly to its very large starch content, the many ways in which it can be prepared for the table, and its low cost should serve greatly to stimulate extension of its use.

The yam has been grown in all parts of Porto Rico for many years, cultural practices having developed in accordance with local needs. Little progress has been made in adopting improved methods of culture or in introducing or disseminating imported varieties. Experiments having in view the introduction of new and improved varieties and methods of culture have been in progress at the experiment station for a number of years.

GENERAL PRACTICES IN YAM GROWING.

The kinds of yams commonly grown in Porto Rico are not particularly sensitive to the type of soil in which they grow, provided the weather conditions are favorable and the proper cultural practice is followed. They are most prolific, however, in a deep, fertile clay, and give poorest yields in light, sandy soils. Some varieties make good yields when grown in heavy, sandy loams. Other varieties yield very well in the heaviest clays where the ridges are sufficiently high to enable the plant to develop a good root system. Compacted and wet soil hinders the growth of the plant and prevents normal root development. Where ridge planting is practiced the roots make a normal growth above the zone of wet soil.

In all frost-free countries yams may be planted at any time of the year, though not always profitably in a long rainy season, nor where there is a protracted drought such as sometimes occurs in Porto Rico and other islands of the West Indies. During the season of rains the heavy wet soil tends to hasten any decay that has started in the seed yams, and too frequent rains retard and stunt the growth of the young plants. On the other hand, a long dry season, if it is followed by drought, is even more detrimental to them. Young plants set out in the dry season may not obtain sufficient nutriment to continue growth after the supply in the seed tuber is consumed. The best time to plant in western and southern Porto Rico, and probably through this island, is after the usual winter drought—that is, from late February to April—when the soil has been left in good condition for planting by the spring rains. Normal growth is then assured. Fall plantings should be made after the time of most frequent rains, but while they are still sufficiently abundant to cause a thrifty growth of the young plants. This particular period is during the last of November in Mayaguez, where the seasons are well defined.

The crop which is planted in the spring matures late in the fall and winter, and may be left in the ground during the dry winter without fear of deterioration. This crop is available for table use through a long period or for disposal at a satisfactory price, depending upon the demands of the local market. Yams intended

for the succeeding crop may be left in the soil until planting time the following spring. In this way good seed may be preserved from decay. Clean seed is an important factor in establishing a good stand of new plants. Should a drought follow planting, the root sections, if they are free from decay, will remain in good condition for many weeks, owing to the thick corky covering of the yam, which enables the seed pieces to retain for a long time sufficient moisture for the growth of the plant.

The yam, though very resistant to severe drought, requires a heavy rainfall for its best production. The plant does not have an extensive root system, nor roots that work deep into the earth, yet it secures sufficient moisture to carry it through long rainless periods. This is observed along the southern and western parts of Porto Rico, where the vines make a moderate growth and show no effect from a drought which injures other vegetation.

In preparing the land for planting care should be taken to bring the soil into good mechanical condition. Substantial ridges or hills should be made, to protect against excessive soil moisture and to secure good aeration of the soil. An excess of water in the soil invariably results in a crop of poorly developed roots. The deep-rooted varieties when grown in heavy unloosened soil are rather angular and irregular in shape, and the production is small.

To avoid such results, ridges of loose earth and vegetable matter should be constructed from 1 to 1½ feet high, depending upon the locality and the subsoil drainage. These ridges should be made by plowing the land deeply and thoroughly and by opening a wide furrow over which the ridge is to be made. In this furrow a few inches of dead vegetable matter should be placed and covered with 2 or 3 inches of earth. This should be followed by another layer of vegetable matter, the layering being continued thus until the ridge is finished. As the vegetable matter decays it causes a settling of the earth. The beds should, therefore, be made a few inches higher than otherwise would be necessary for the growth of the plants.

These ridges may be cheaply constructed with a plow, the only hand labor needed being in the application of the vegetable matter and the final rounding up of the ridge with hoes. The layers of manure or other vegetable matter in the ridges insure a loose, well-aerated medium for the development of the roots, and seem to be required for their best development. The ridges do not need to be large in sand or sandy loam unless the subdrainage causes poor aeration of the strata occupied by the roots. In these soils the humus-providing material should never be omitted.

When seed is scarce, either crowns or entire small tubers may be successfully used, or a cross section of a slender, cylindrical root

may be planted. The crown or upper part of the root is the most satisfactory part for planting, because it is less desirable as food and better able to withstand exposure, bruises, or unfavorable weather longer after planting than other parts. When it is profitable to market the crop before the proper time to plant a new crop, the crowns may be left in the soil for a number of weeks after the remainder of the root has been removed. This can be done by removing from one side of the plant all the soil until the entire edible root is exposed, dividing the root at the desirable point, and removing the lower section. Care should be exercised to avoid injuring any of the feeding roots which are spread laterally in all directions from the crown. The hole from which the earth is removed should be immediately refilled so that the plant can continue to grow and develop strong buds. Each plant has from two to four buds or eyes. The lower part of the yam has a much higher water content than the crown, and consequently it is more susceptible to injury and decay than the upper part. It is also slower in starting into growth than the upper part, and should not be used unless seed yams are scarce.

The experiment station found that a good percentage of sections (taken from the largest roots) sprouted when placed in a cool, shaded place, and made a normal growth when transferred to the field. The crown and part just below usually send out from two to four sprouts promptly, and may be divided longitudinally with good results provided the piece of the root is large enough to supply nourishment for the young plant.

To secure heavy yields, seed pieces of good size should be planted. One to 2-ounce pieces are often planted in Porto Rico, but pieces weighing from 4 to 5 ounces should be used. Tests made at the station with different sized seed pieces of common varieties and with entire tubers of some of the small-rooted varieties showed that a good gain in yield was made by using large rather than small seed pieces.

TREATMENT OF SEED ROOTS.

Poor stands of plants are usually caused by sections of the roots decaying before the vine growth starts. The following treatments were given a number of seed pieces to test their efficacy in preventing the entrance of decay through the cut surface of seed pieces:

The cut surfaces of one lot were covered with air-slaked lime; those of another lot were exposed to the sun for one day; two lots were treated with Bordeaux mixture, one as soon as the roots were cut and the other after drying in the sun for 10 hours. An untreated lot was placed in the storage house as soon as it was cut.

A small-rooted type of the Potato variety and a large-rooted kind of the St. Vincent were used in this test. The yams were harvested 15 days before treatment, and after treatment were stored in a room having a high humidity and temperature of probably 80° F. Such conditions favor the rapid decay of the roots.

Two weeks after the treatment was applied the roots were examined. It was found that where the lime had been applied 40 per cent of the pieces were decayed, although none of them was entirely destroyed. Where Bordeaux mixture was applied to freshly cut surfaces only 16 per cent of the pieces showed decay, and all could be planted. The application of Bordeaux mixture to the lot that had been previously dried resulted in little improvement over the check. In the untreated lot more than three-fourths of the pieces were considerably impaired and a few were entirely consumed by disease, while only 12 per cent were in normal condition. In all cases a percentage of the decay on the cut surfaces developed from bruises on other parts of the roots, and in some instances from infections received after the roots were cut. The Potato variety was slightly less injured than the St. Vincent.

DISTANCE APART TO PLANT.

The distance between the seed yams in planting depends much upon the normal growth of the variety. One foot apart in the ridges is sufficient for varieties producing small roots, but the larger-rooted kinds require a distance of 1 to 2 feet. In Porto Rico it is the practice to plant much farther apart than this, sometimes twice the distance. This is hardly wise, because a given area will produce much more when close planting is practiced. The cost will be lower, too, since the only cultivation required after planting is occasional weeding and maintaining well-formed ridges. The expense involved in cultivation consists mainly in plowing the land, securing suitable vegetable matter or manure for the ridges, building the ridges, and placing poles for the support of the vines. Any decrease in area prepared for planting results in a proportional decrease in expense, equally good preparation being necessary for planting at any distance. Where hill planting is practiced the hills should be from 3 to 4 feet apart each way, depending upon the type of soil. The wider distance is necessary in heavy soils because the hills must be made higher than in more open soil to insure good aeration and drainage. The closest planting will be found convenient in light soils. The seed should be covered with 2 or 3 inches of earth to prevent it from drying in case drought follows, or from being washed out by heavy rains.

TESTS WITH FERTILIZERS.

Cultural practices that have been in general use in Porto Rico for yams do not include fertilization, and the fertility of the soil is seldom considered when the choice of a location is made. The prevailing belief is that soils suitable in texture are sufficiently rich for yam production, and a satisfactory crop can be expected from soil which is properly prepared. The home garden in Porto Rico is generally made near the house to prevent petty stealing. This land has been used for many years and would be expected to yield good returns.

The station has tested both stable manure and chemical fertilizers to determine their effects on different varieties of yams. The soil where the experiments were made is a level tract of heavy, dark, clay loam built by washings from the hills of the interior. In all parts of the field, except where in recent years a slight excess of humus and vegetable matter has been deposited on the surface, it is even in quality. Neither the surface soil nor the subsoil drains well, and ridges on which the crop was planted were built high enough to prevent any injury by subsoil water. The land was plowed deeply, and the ridges were built with plow and shovel preparatory to planting. When finished the oval ridges were 6 feet apart and about 1½ feet high, and the soil was of good texture throughout. Just before planting the fertilizer was applied to the shallow furrow which had been made in the top of each ridge and thoroughly mixed with the soil. The stable manure was worked deeply into the center of the ridges and two applications of nitrate of soda were made near the surface after the plants started growth. Tests with chemical fertilizers were continued over four years with the Potato and Agua varieties, and for three years with the Barbados and Guinea varieties. From 12 to 30 plants of each variety were grown yearly in each plat, the number varying in different years according to the size of the plat. Plants of the Potato variety were placed 1 foot apart, while the Agua, Barbados, and Guinea varieties were each planted 1½ feet apart. The basic formula of the fertilizer used was 5 per cent nitrogen, 8 per cent phosphorus, and 12 per cent potash, and the fertilizer was applied at the rate of 3,000 pounds to the acre. Plantings were always made as soon as the spring rains occurred, which was in late March or early April. The crop was not dug until the following February or March, so that the roots might remain in the ground until planting time to insure first-class seed.

The table following shows the average yield per hill of the different varieties used in these tests in the fertilized and check plats for all the harvests while the work was in progress.

Average yield, in pounds per hill, ridge planting, of four varieties of yams on fertilized and unfertilized plats during the years named.¹

Variety.	Fertilizers applied.					Check.
	Stable manure.	Phosphorus and potash.	Phosphorus and nitrogen.	Potash and nitrogen.	Phosphorus, potash, and nitrogen.	
Potato:	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
In 1913.....	3.9	4.05	3.55	3.6	5.17	3.45
In 1914.....	1.6	1.6	2.4	1.6	3.6	2.3
In 1915.....	3.4	3.4	3.15	4.33	4.23	3.23
In 1916.....	1.57	1.41	1.78	2.12	2.82	1.84
Average.....	2.62	2.62	2.72	2.91	3.95	2.75
Barbados:						
In 1913.....	8.4	7.1	6.5	4.1	7	4.8
In 1914.....	7	4.5	6.2	3.4	7	5.9
In 1915.....	4.8	4.5	5	6.36	5.5	4
Average.....	6.73	5.37	5.9	4.62	6.5	4.9
Guinea:						
In 1913.....	3.17	3.17	2.83	3	4.8	3.33
In 1914.....	.6	2.4	2.1	2.1	1.1	1.7
In 1915.....	1.2	.54	.96	1.04	10.4	1.7
Average.....	1.66	2.03	1.96	2.05	5.43	2.24
Agua:						
In 1913.....	3.37	4.5	4	4.2	4.62	4
In 1914.....	4.2	2.5	1.4	3	2.5	3.4
In 1915.....	2.2	2.4	3.3	3	4.6	3.3
In 1916.....	1.8	1.4	3.3	1.7	3.05	1.9
Average.....	2.89	2.7	3	2.97	3.69	3.15
Average for four varieties.....	3.475	3.18	3.395	3.14	4.89	3.26

¹ Each plat was about one-twentieth acre in size.

This table shows that there was a wide range in yield of each variety in the different plats during a given year, and that large differences were not consistent for all the plantings; also that the different fertilizers produced only small differences in the average yield of a number of crops. Where all three chemical ingredients were given, the average production for all varieties combined was considerably higher than where one element was omitted. It was also higher than where stable manure was given in all except the Barbados variety, where the yield from stable manure slightly exceeded it. Where all three elements were given, the plat made a gain of more than 50 per cent over the check. In the test where nitrogen was omitted and in that where phosphorus was omitted, the total average yields were less than where no fertilizers were given. The plat receiving no nitrogen gave a lower combined average production than any other plat except the one receiving no phosphorus.

The combined average production by the plat treated with stable manure was greater than that of any other plat except the one receiving a complete chemical fertilizer, which exceeded it by 40 per cent. As the application of only two of the three elements—nitrogen, phos-

phorus, and potash—gave only a small increase in combined average yield over the check plat in but one plat (that where nitrogen and phosphorus were given), and the plats where nitrogen or phosphorus was omitted gave actually a lower combined average yield than the check plat, it seems clear that no one element can be considered as the limiting factor in production, and that a complete mixture only should be used where fertilizers are applied.

As the land utilized in this test had been in use for several years just prior to planting to the yams, and the yield was below the average usually obtained in Porto Rico, a better return was to be expected from fertilization than would be looked for from newer soil.

In 1910 the four varieties used in the above-mentioned experiments were used in experiments to compare stable manure applied in different amounts with complete chemical fertilizers of varying amounts, and with a complete fertilizer made up of organic and chemical ingredients. In these experiments stable manure was applied to two plats, one receiving the manure at the rate of 10 tons per acre, and the other at the rate of 20 tons per acre. Two plats were treated with a mixture of nitrate of soda, acid phosphate, and sulphate of potash, the mixture containing nitrogen, phosphorus, and potash in the proportions of 3, 6, and 9 per cent, respectively. One plat received three-fourths ton per acre of the fertilizer mixture and the other $1\frac{1}{2}$ tons. Another plat received $1\frac{1}{2}$ tons of a mixture having an analysis similar to that of the chemical mixture previously mentioned, but made from tankage, bone meal, and sulphate of potash.

The quantity of roots harvested from these plats showed only small differences. No increase in yield was realized by replacing nitrate of soda and acid phosphate with tankage and bone meal. The plat to which 10 tons stable manure was given yielded nearly 10 per cent more than the check plat or the plats which received an all-chemical fertilizer. The plat which received 20 tons per acre yielded slightly less than the check plat. This heavy application resulted in a marked increase in the vine growth at an expense of the crop of roots harvested. Ten tons of manure is sufficient for application. It may be in excess of the amount required for rich soils, since it is not spread broadcast as for most other crops, but is placed in ridges that are several feet apart. When selecting lands preparatory to planting yams, and when using fertilizers on them, it must be borne in mind that the plants should make a thrifty growth if a good crop of roots is to be expected. Frail or extra heavy vines seldom give a good yield.

TESTS OF VINE PRUNING.

To test the effect of pruning on yams, plantings were made of Guinea and Potato varieties, because they are representative of large

and small rooted kinds. The ridges for planting were made in the usual way and in soil that was well adapted to the crop. The plants made thrifty growth and were pruned back each week, the Guinea to 6 feet and the Potato variety in one plat to 2 feet, in another to 4 feet, and in a third to 6 feet. Plats of each variety were left unpruned for checks. The vines of the Potato variety continued thrifty through the season, but the pruned vines of the Guinea variety lost some of their rich color before fall and became dry several weeks earlier than the check plat. The harvest from the pruned plants of the variety Guinea was only 46 per cent of the yield obtained from the check plat. The yield from the Potato variety was 29 per cent from the vines pruned to 2 feet, and 46 per cent from those pruned to 4 feet, while the yield from plants pruned to 6 feet was 68 per cent of that obtained from the check plat.

This clearly shows that the vines should not be pruned or injured if the best results are expected. Where the vine supports were insufficient or allowed to blow over and were not promptly replaced, there was a marked decrease from the normal yield. Vines not provided with supports, but allowed to creep over the ground, made very poor growth and gave low yields of roots.

HARVESTING.

Such implements as mattocks, heavy forks, and spades are required for harvesting yams, because the earth must be removed to the depth of the roots. The large roots fit firmly in the soil and it requires great care to remove them without injuring them. They will be bruised if pulled or pried out before the soil around them is well loosened or removed. The process of digging deep-rooted types in heavy soils is difficult in dry weather, because the roots are often enlarged near the lower end and are easily injured during removal from the hard soil. Roots of all varieties of yams are subject to rapid decay if they are bruised or the skin is broken. When bruised to any depth they soon become unfit for use. The yam, like the potato, is used while it is fresh, and every precaution should be taken to keep it from decaying, so that the entire crop can be utilized.

VARIETIES AND CULTURAL TREATMENTS RECOMMENDED.

Among the following are some well-known varieties that have been grown for years for home and market consumption in every part of Porto Rico. Some others mentioned are not as yet well known, having only recently been introduced into the island, and probably into the West Indies. A number of the latter varieties have desirable properties, and are considered among the best in flavor and quality, deserving trial in all parts of the island. The varieties discussed in

this bulletin were under cultivation at the experiment station at Mayaguez and do not include all the large number of varieties known in Porto Rico. (Pl. I, fig. 1.)

GUINEA.

The yam locally known as Guinea is a variety of the species *Dioscorea sativa*, and is one of the most popular yams in Porto Rico. It is widely distributed over the island, upland clay soils to which it is best suited being accessible to almost every family. Its production is probably greater than the combined yield of all other varieties grown in the island. In the city markets it retails usually at a somewhat higher price than any other kind except the variety known as the Mapuey morado. The vine grows quickly and matures earlier in the fall than any of the other varieties under discussion. The roots, though generally cylindrical in shape, are occasionally divided into two, three, or even four parts at the lower end (Pl. I, fig. 2). In a normal plant the root should measure about 4 inches in diameter, 12 or 14 inches in length, and weigh about 6 pounds. The outer covering of the root is thick, rough, and corky, and the edible part is pure white. The texture is uniform throughout, fine-grained, brittle, easily bruised, and free from fiber. The starch content of normal roots, as determined by the chemical department of this station, is 24 per cent of the fresh root. When cooked it is firm, tender, and granular, retains sufficient moisture to be palatable, and has a rich, sweet, and altogether pleasant flavor. For table use it ranks among the best.

Any part of the root may be used if planted at a time when the moisture is sufficient but not excessive. However, the top part of the yam yielded considerably more than the other parts when planted at the station. The yield from plantings of middle or lower sections was about equal. The maximum size of cuttings for plantings seems to be about three-fourths pound, owing to the fact that larger pieces are frequently attacked by decay after they are planted. This is true more especially when the roots have been injured or subjected to unfavorable weather. Large top sections are preferable to large center sections when yams are desired for market. The roots produced by the former, though fewer in number, are much larger and therefore always sell more readily than those produced by the latter. When roots are desired for planting the following year, center sections weighing about three-fourths pound should be preferred over top pieces or crowns. A number of yams develop along the margin of the cut area of these sections and these in turn develop into small or medium-sized roots. The formation of three to seven yams on one seed piece greatly increases the number of crowns for



FIG. 1.—VARIETY TEST OF YAMS, RIDGE CULTURE, PORTO RICO STATION.



FIG. 2.—SPECIMENS OF GUINEA YAMS (*Dioscorea sativa*).



FIG. 1.—HILL OF POTATO YAMS; WEIGHT, 12.5 POUNDS.



FIG. 2.—POTATO YAMS; LARGE VERSUS SMALL SEED TUBERS. PILE ON RIGHT, SEED WEIGHED 135 GRAMS; ON LEFT, 45 GRAMS.

future planting. One-half pound seed pieces develop fewer roots, and seed pieces weighing one-fourth pound or less seldom yield more than one yam per hill.

POTATO.

A small rooted variety (Pl. II, fig. 1) resembling an Irish potato and introduced from Africa a few years ago has been distributed to many parts of the island. This variety is known in Porto Rico as the Potato yam. In some places it is considered among the best for home planting, and in a few of the city markets of Porto Rico it is bringing good prices. The Potato yam should be planted in all parts of the island except where the soil is light and sandy. It will not thrive in such soil.

The vines of the variety are slender, round, of moderate growth, and remain green later in the dry season of winter than any other kind, except the variety known as Congo, the vines of which grow throughout the year. A dozen or more short, strong, sharp spines develop between the nodes of older parts of the vine. The leaf petiole is round and slender, has a few spines resembling those on the vine, and at its base has two long sharp spines. The leaves appear alternately. The edible roots develop near the crown of the plant much the same as sweet potatoes. They are oval and vary up to 8 inches in length, and $2\frac{1}{2}$ inches in diameter. As they are small and not easily injured, these roots can usually be kept longer after being harvested than the large-rooted kinds. They are smooth, dark grayish-brown, and at a distance of a few feet are likely to be mistaken for the Irish potato. The skin is very thin and tough, and may, after being broken, be pulled off in strips resembling thin pieces of cherry bark. The interior of the root is over 23 per cent starch. It is white, brittle, and firm, and practically free from fiber when not allowed to remain too long in the soil. However, roots which are left in the soil until late in the winter sometimes have a few long and rather strong, longitudinal fibers. When cooked the roots are fine-grained, tender, and sweeter in flavor than most other varieties.

Since the small yams develop in the surface soil and are not hindered by a compact subsoil, the Potato variety thrives best in rich soil and better than most other varieties in heavy clays. This variety yields poorly in sandy soil, and produces angular or flattened tubers in heavy, compact soil. The land selected for planting should be kept free from weeds and grass, so that cultivation will be unnecessary during the first five or six weeks of the plant's life.

The table following shows the results of tests made to determine the effect of planting large and small roots of the Potato variety at different distances, as well as the result in yield of planting on level land and on ridges. The tests were made with roots slightly above

the average size for marketing, their average weight being 135 grams, and with the smallest-sized roots suitable for table use, weighing 45 grams. (Pl. II, fig. 2.)

Yield of roots in pounds obtained from planting small and large-sized roots at different distances on level land and on ridges.

Test.	Level land planting.				Test.	Ridge planting.			
	Seed roots planted.	Distance of planting.	Yield per hill.	Yield per acre.		Seed roots planted.	Distance of planting.	Yield per hill.	Yield per acre.
	<i>Grams.</i>	<i>Feet.</i>	<i>Pounds.</i>	<i>Pounds.</i>		<i>Grams.</i>	<i>Feet.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1.....	135	2 by 2	3.86	42.095	5.....	135	1	4.0	28.372
2.....	135	4 by 4	6.38	17.368	6.....	135	2	6.6	23.410
3.....	45	2 by 2	1.9	20.691	7.....	45	1	3.6	25.524
4.....	45	4 by 4	3.42	9.310	8.....	45	2	5	17.905

It will be noted that the large seed roots produced a heavier yield than the small roots; also that the average weight per hill of the yield from small seed roots was only 65 per cent of the yield from the large seed where different distance plantings and ridge and level land plantings are considered. The roots produced from large seed roots were also considerably larger than the roots produced from the planting of small roots.

The figures given under ridge planting show that the yield per hill where large roots were planted was about the same for plantings 2 feet apart in ridges and 4 by 4 feet apart on level land; and that the yield per hill from planting small tubers was considerably heavier where planted in ridges than from the yield secured from level plantings. (Pl. III, figs. 1 and 2.)

For level land planting at distances of 2 by 2 feet the yield in weight of roots harvested per hill was less than when the plantings were made at 4 by 4 feet when the seed roots of the same size were planted. The total yield per acre, however, was the reverse, the 2 by 2 feet plantings giving more than double the yield of the 4 by 4 feet plantings (Pl. IV, fig. 1). The difference in yield was less marked for plantings made 1 or 2 feet apart in the row. The roots grown in closely planted areas are much smaller than those produced when the plants are farther apart. Therefore the profit accruing from close plantings would not be in proportion to the yield were the crop to be sold for table use, because the larger roots bring a higher price in the local markets than the smaller ones. Probably the most economical plantings would be at distances of 3 by 3 feet.

The starch content of the fresh roots of the Potato variety is 23.55 per cent. This feature, together with its heavy yield, makes it a most desirable yam. It grows well on level land where the drainage is

good and the soil loosened to a good depth, or on low ridges. As a consequence, the land is prepared more quickly and at less expense than where large ridges are required.

TONGO.

This variety (Pl. IV, fig. 2) was sent to the Porto Rico experiment station in 1915 from New Guinea through the Bureau of Plant Industry, United States Department of Agriculture. It was known as S. P. I. No. 31923, and was identified by P. J. Wester² as *Dioscorea aculeata*, locally known as the Tongo. It has proved so satisfactory that it deserves recommendation as a very promising yam for Porto Rico. The plant so closely resembles the variety called Potato that it would not readily be distinguished by the casual observer. However, its leaves are somewhat larger and slightly different in form. The foliage of both is light green and does not become dry until late in the dry season. Neither of these varieties produces as heavy a vine growth as most other kinds. Each variety sends out a number of underground stems that are 1 to 4 feet long. They are found near the surface of the ground. These stems are set with long, sharp thorns, which are a hindrance at harvest time.

The Tongo prefers a fertile loam soil, although good crops were produced in rather heavy clay at the station. Since the roots of this variety do not grow as deep as those of some other varieties, low banks are sufficient to enable them to attain normal development. Weighings were made at the 1916 harvest to determine the relation of the size of the tubers produced to the size of the tubers planted. It was found that the tubers obtained from the 235 plants grown from large seed tubers were on the average 17 per cent larger than those obtained from an equal number of plants grown from small tubers. The edible roots are larger than the Potato yam, but are small compared with the largest rooted yams. They are produced in hills much the same as sweet potatoes. The roots vary in size from those too small to be of value for table use to 10 inches in length and 3 inches in diameter. They are smooth, except for numerous short roots that grow on them. These are grayish-brown and much more numerous on the upper half of the roots. The skin is very thin and resembles that of the Potato yam. However, it is not as tough and does not separate so easily from the inner part of the root as is the case with the Potato yam. The edible part of the root retains its snowy whiteness after being cooked, has an agreeable texture, is very fine-grained, and is sweet and rich in flavor.

Planting roots weighing about 4 ounces gave best results in tests at the station. Roots twice this size made a slightly greater yield. Those weighing but 2 ounces yielded almost 40 per cent less than for

² Philippine Agr. Rev., 9 (1916), No. 3, p. 194.

4-ounce seed roots. Plantings of roots that were cut into halves, each piece weighing 4 ounces, gave as high a yield as whole roots having the same weight; while the yield from the upper and the lower halves was practically the same.

This variety yields about the same as the Potato variety. It keeps well after being removed from the ground, has first-class table qualities, and contains 22.32 per cent starch. In all localities it should be thoroughly tested.

P. J. Wester,³ in writing of the value of the above-described variety, states:

There are several well-recognized varieties distinguished by the prevalence and size of subterranean spines, and by the size, form, and quality of the tubers, some being large, others small, smooth, or partly covered with hairy roots, dry and mealy to soggy, sweet, or devoid of sugar. * * * In quality the best varieties outrank all other crops in the Philippines and the yield is very satisfactory.

PURPLE CEYLON.

This yam, so called because of the purple color of its flesh, was imported in 1908 from Ceylon for the experiment station, and, on account of its pleasing flavor, has become a favorite variety. Its distribution has been exceedingly slow, owing to its popularity as an edible. Seldom more than the crown of the root is left for planting, and as a result succeeding plantings have not increased. It should be propagated on a larger scale and an effort should be made to extend its planting to localities where it is not yet known. The parts of the root for planting need not be confined to the crown. Any part may be utilized with the assurance that it will yield a profitable crop. The crown need not be planted entire, but may be divided into two, four, or even six pieces. This may be done by cutting through the rootstock and leaving a growing point on each section. At the experiment station $\frac{1}{2}$ -pound seed pieces cut from the lower part of the root produced an average of nearly 5 pounds per plant. This is a splendid weight for a root of the Purple Ceylon variety, and corresponds with that produced by equal-sized pieces of the basal or upper part of the root. In cases where the upper part was divided into one-fourth pound pieces and a section of the rootstock was left on each piece the average yield was slightly less than 5 pounds per plant. Seldom, if ever, has any seed root failed to produce a plant at the station when soil and weather conditions were favorable. When the rootstock or sections are planted the vine makes a gain of several days' growth over shoots which sprout from cuts taken from the lower part of the root. However, they do not continue to grow over a longer period, for the latter remain green some days after the former have wilted and dried.

³ Philippine Agr. Rev., 9 (1916), No. 3, p. 194.



FIG. 1.—RIDGES 6 FEET APART. PLANTS 1 TO 2 FEET IN RIDGES.



FIG. 2.—HILL PLANTING 2 BY 2 FEET APART.
POTATO YAMS; RIDGE VERSUS HILL PLANTING.

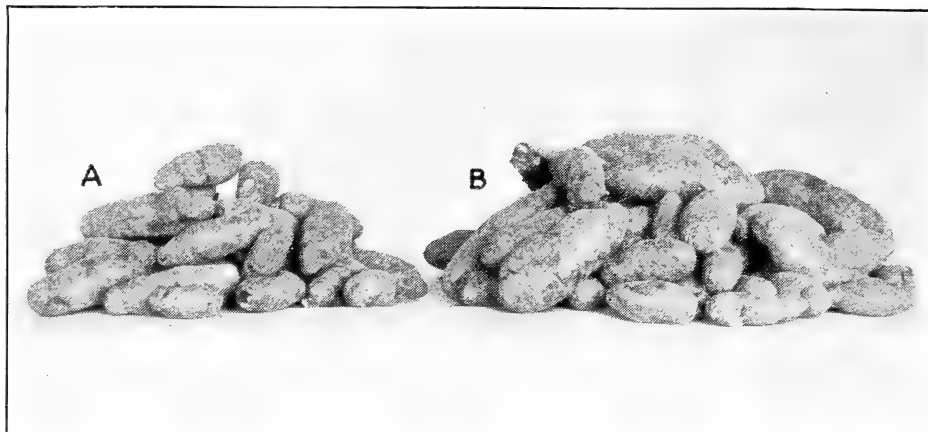


FIG. 1.—RESULT OF EXPERIMENT IN SPACING PLANTINGS OF POTATO YAMS.
PILE ON RIGHT, 4 BY 4 FEET; ON LEFT, 2 BY 2 FEET.

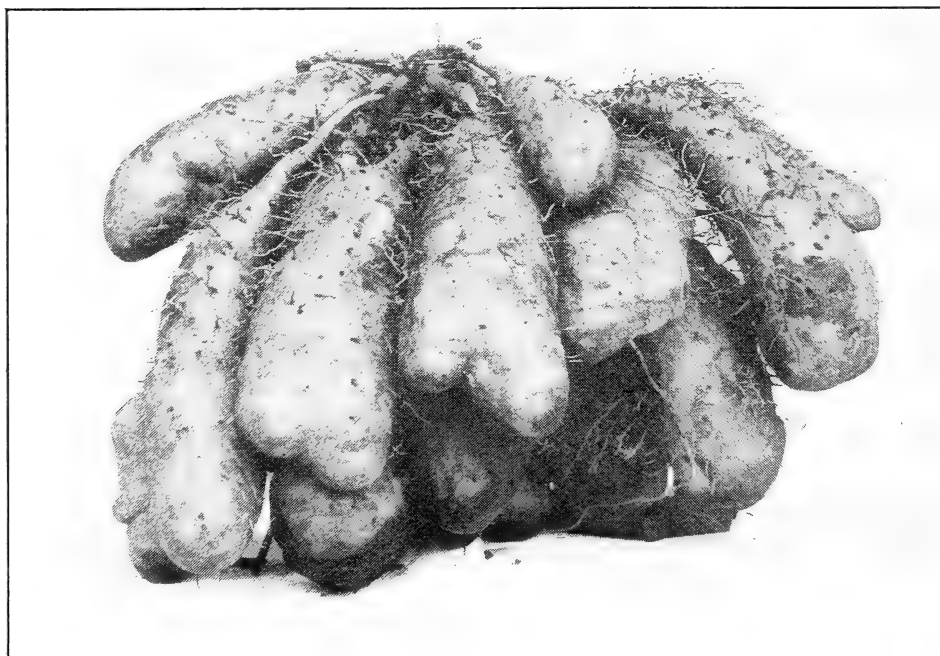


FIG. 2.—A HILL OF TONGO YAMS (*Dioscorea aculeata*), S. P. I. No. 31923.

The vines of this variety are long, large, vigorous, and angular and have four sides. A membrane, or wing, running the length of the vine is found at each corner. The leaf petiole is from 5 to 7 inches long and has five wings which are formed at its angles, the same as those on the vine. These extend into the five largest veins on the lower surface of the leaf. Enlarged purple sections $\frac{1}{2}$ to $\frac{3}{4}$ inch long grow near each end of the petiole. The blade of the leaf is 6 by 4 or 5 inches, and it is dark green. A few small air tubers 2 by $1\frac{1}{2}$ inches develop on the vines of this variety. The edible root is almost spherical or made up of two or three large round lobes. However, it never forms long, deep-growing roots. Usually a slight depression occurs at the union with the rootstock. The surface of the root is rough, corky, and dark gray. The interior is a rich purple and has some areas where the coloring is not so intense. The starch content in the fresh root is 20.03 per cent. After being cooked, this yam has a smooth, even texture and retains its dark purple color, causing it to resemble the well-known variety locally known as Mapuey morado. Its flavor is rich and pleasing and has been highly complimented by all who tested it. Unfortunately, the distribution of the Purple Ceylon, as well as the area planted to it, has been somewhat restricted. Its edible qualities cause the entire crop to be consumed year after year, and the result is that only the rootstock is left for planting.

DIOSCOREA SATIVA.

The yam grown at the station as S. P. I. No. 31922 has been identified, from specimens sent from here, by W. E. Safford, of the Bureau of Plant Industry, United States Department of Agriculture, as a variety of *D. sativa*. This variety, originally from New Guinea, is of all the varieties tested the only one that produces vine tubers, or "air potatoes," of sufficient size to be suitable for table use. Its yield of these is sufficiently high to justify its being planted more extensively. The vines of this yam are large and make rampant growth. Under normal field conditions they sometimes attain a length of 25 feet. The leaves appear opposite on the vine and have large, almost round petioles that are 5 or 6 inches long. The blades are from $4\frac{1}{2}$ to 6 inches in width and from 6 to 7 inches long. Near each end of the petiole there is a purplish section which is from $\frac{3}{4}$ to 1 inch long and considerably larger than the remainder. The edible roots are irregular in shape and usually develop from the rather long rootstock four to eight finger-like lobes, some of which are divided or branched. The whole roots weigh only 1 or 2 pounds. (Pl. V, fig. 1.) The skin is very thin and tough, and would be smooth were it not for numerous small rootlets. The inner part of the skin and

large areas in the inner part of the root are of a light purplish color, though the predominant color of the edible portion is light yellow. These roots usually are tough and difficult to injure, and therefore keep better than most other kinds. They are fibrous and hard when cooked and not of pleasant flavor. The air tubers, or "air potatoes," grow within the axils of the leaves in great numbers when conditions are favorable. In fact, the average number produced per vine on the crop at the station for 1917-18 was 17; the total weight was 3.5 pounds.

These air tubers vary greatly in shape, but for the most part they are shaped somewhat like an egg, though more elongated at the smaller end. Some are almost spherical. Others are flattened, resembling a wide-open fan, edged with round, smooth notches. These tubers are smooth, except for numerous small indentations, and the interior is yellow, firm, though not hard, and free from fiber. When cooked, the air tubers of this variety are of excellent texture and rank among the best yams in flavor. The keeping qualities of the "air potatoes" are far better than those of any other yam tested. Of those examined at the station, not one decaying "air potato" was found, although they were handled in the same manner as other yams, and in many cases were kept in storage for months. Their keeping qualities are partly due to their firm outer skin and partly to their size. They are smaller than most other kinds and are less likely to be injured at harvest time than roots that must be dug. The starch content of the "air potatoes" of this variety, calculated on the fresh sample, was 12.46 per cent, and of the edible root 17.95 per cent.

DIOSCOREA CHONDROCARPA.

A variety of this yam was imported from New Guinea and sent to the station as S. P. I. No. 31920 through the Office of Foreign Seed and Plant Introduction of the Bureau of Plant Industry, United States Department of Agriculture. It has been grown for a few seasons in the station's plat (Pl. V, fig. 2) and has been found to be one of the heaviest-yielding yams. It has a high starch content, that for the fresh yam being 25.32 per cent. While it is not so rich and agreeable in flavor as some other yams, it is nevertheless recommended for trial in all parts of the island.

The yield of this variety when planted in suitable places averaged over 5 pounds per hill, and many individual hills produced roots weighing twice this amount. The yams are generally flattened or fan-shaped and divided along the lower margin into many rounded lobes. The rootstock is white, large, and woody, and the upper part of the edible portion is somewhat tough. The hardness and yellowish color, however, gradually diminish at the center, and at the lower

portion the lobes are very tender and almost pure white. The skin on the upper portion is rough and corky; on the lower portion it is thin and easily broken. The roots are susceptible to injury at harvest time, because they develop well below the surface of the ground, have brittle interiors, and are large and oddly shaped. So that harvesting may be facilitated with least possible injury to the roots, banks should be made as high as those required for the longer-rooted kinds. Injured roots decay much more rapidly than those of most varieties, but uninjured specimens retain their tenderness and good texture as long as any other large-rooted kinds. Upper sections of the root-stock, when planted simultaneously with equal-sized pieces from the lower part of the root, made an average yield per plant which was practically the same for the different plats. It would therefore seem that under favorable conditions any part of this yam can be used for planting.

AGUA.

The Spanish name Agua, meaning water, is given to a number of varieties of *Dioscorea alata*, and is used to indicate one particular type of yam that is probably more widely known than any other in Porto Rico, but which is usually ranked as a second-class yam. Its popularity is in great measure due no doubt to its abundant yield on a wide range of soils and to its peculiar keeping qualities after being removed from the ground a long time. The vines of the Agua are moderate growers and four-sided, having rather wide membranous wings running along their corners. The margins of these wings, like the margins of the leaves, are purplish. The leaf blade is normally 4 or 5 inches long, and $3\frac{1}{2}$ or 4 inches wide, and the petiole is about 5 inches long. The large cylindrical or tapering roots are very dark, rough, and thick-skinned. While the outer layer of the skin is tender, the inner yellow layer is exceedingly hard. The interior of the root has at the base a marked brownish tinge, which decreases toward the lower end. When boiled, the root has a slightly yellowish watery color. The edible portion contains considerable fiber, but otherwise the texture is of good quality. This variety sells at a lower price than most yams, because it lacks the rich flavor found in other varieties. Like all other large-rooted varieties, it should be planted on high ridges. In Porto Rico the notion seems general that to produce roots of marketable size, either the crown or top of the old root should be planted. Experience has shown, however, that almost identical results can be obtained from top or bottom sections when planted in well-prepared banks.

The starch content of this variety was found to be 16.76 per cent of the fresh yam. This is considerably below the average for all

kinds, and 50 per cent below that of the varieties giving the highest starch content.

A variety of *D. alata* (Pl. VI, fig. 1) from New Guinea, was lately introduced through the Bureau of Plant Industry, United States Department of Agriculture, as S. P. I. No. 31919, and seems to be well adapted to conditions in Porto Rico. The roots are slender and very long, and, as a result, they can not, except with difficulty, be harvested without injuring them. The variety does not withstand drought as well as some other varieties and its yield is slight, a production of 3 pounds per hill being exceptional. For these reasons, this yam can not be recommended for general planting. The roots are thick-skinned and rough. The interior is somewhat coarser than that of most other varieties, has a tinge of brown, and like most water yams is fresh in appearance. When cooked it has little sweetness and lacks richness of flavor.

Another yam, said by P. J. Wester to be a *D. alata* variety, and introduced from New Guinea under S. P. I. No. 34861, has shown itself especially well adapted to the heavy clay soils of Porto Rico. It possesses a richer and more pleasing flavor than the *D. alata* variety above mentioned. Its roots have a diameter of $2\frac{1}{2}$ to $3\frac{1}{2}$ inches, and are very long, sometimes attaining a length of $3\frac{1}{2}$ feet in one season (Pl. VI, fig. 2). The edible roots do not grow perpendicularly but at an angle, and often almost horizontally along the bank. Inasmuch as the roots can not pierce hard earth, the banks should be large and well-prepared, so that a well-shaped product will be insured. Otherwise, the roots on reaching the bottom of the bank will be deflected. Sometimes they turn at a right angle or in such a manner as to form a complete circle when the point reaches the top of the bank. On account of these peculiarities of growth, this variety is difficult to dig without injury to the roots.

DIOSCOREA CAYENNENSIS.

A variety of this species is grown in many parts of the island and is well known in some localities. In Mayaguez it is called "Congo amarillo," but in the San Juan market, where it is found in greater abundance than other kinds, it is known as "Yellow Guinea." It thrives much better in sandy soils than most yams, and is therefore preferred in some sections. The edible root of this variety closely resembles the "White Guinea" in shape and size, though the skin is thick and somewhat more corky than the latter. The large roots attain a length of probably a foot, are rather cylindrical, and average a weight of 4 or 5 pounds in seasons when weather conditions are favorable. The interior of the starchy root is a rich light yellow and turns dark brown when exposed to the air. It is smoother

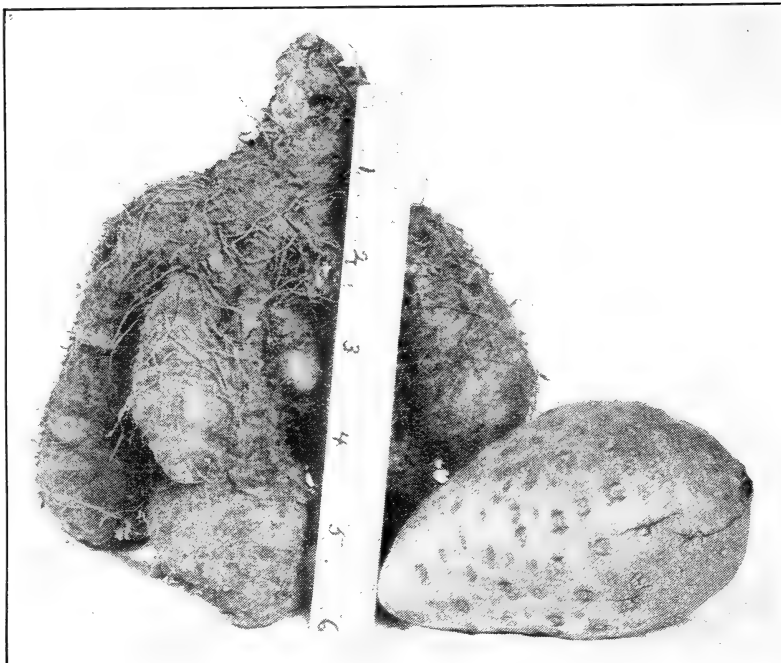


FIG. 1.—EDIBLE ROOTS AND AIR TUBERS OF YAM (*DIOSCOREA SATIVA* VAR.), S. P. I. No. 31922.

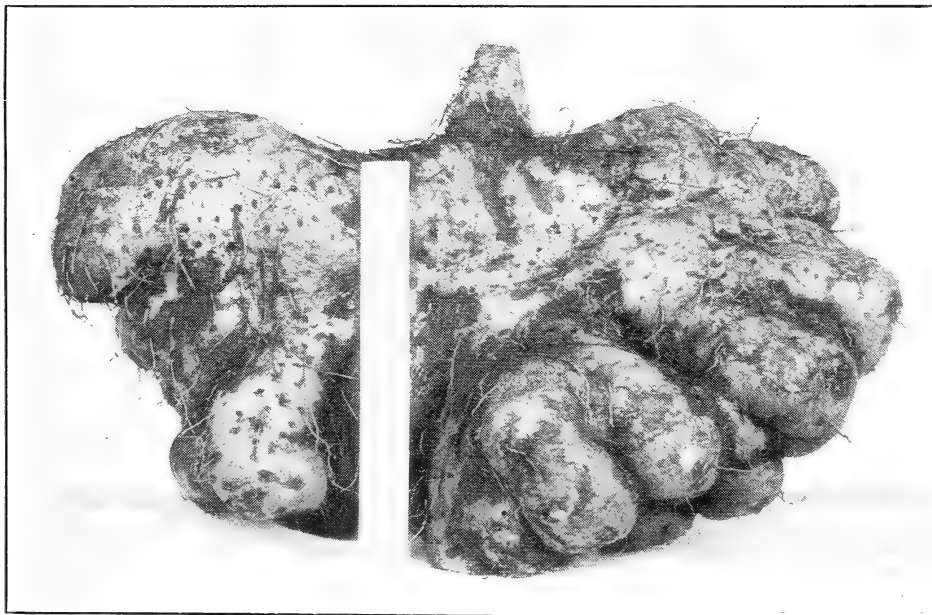


FIG. 2.—SPECIMEN OF YAM (*DIOSCOREA CHONDROCARPA*), S. P. I. No. 31920.



FIG. 1.—SPECIMENS OF YAM (*DIOSCOREA ALATA*), S. P. I. No. 31919.

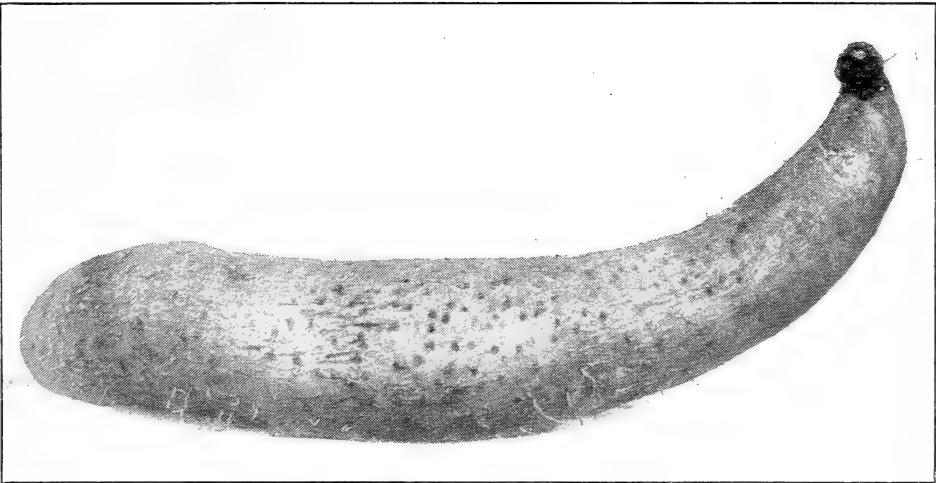


FIG. 2.—SPECIMEN OF YAM (*DIOSCOREA ALATA*), S. P. I. No. 34861.

and more even-grained than the water yams and not less so than the roots of the White Guinea, Potato yam, or Congo varieties. It is rich yellow and of good texture when cooked. The flavor is pleasant and compares favorably in richness with the best yams. The vines of this variety are round, small, and very strong, and make a moderately vigorous growth. Unlike most varieties, this variety makes a slow growth throughout the year, and it is apparently unaffected by the long dry winter. The leaves and vines are pointed, tough, glossy, very dark green, and average about 5 inches in length and 3 inches in width.

MAPUEY MORADO.

The Mapuey morado is a variety well known throughout Porto Rico, where it is considered superior in flavor to any other yam. Its production per hill, however, is so low, unless the plant is grown under the most favorable conditions, that only a small area of land is devoted to it. It succeeds best on a very fertile, well-drained, and thoroughly prepared upland. In such places it yields sufficiently well to be profitable, because it always sells at a considerably higher price than other kinds. The club-shaped roots of this variety develop in hills near the surface of the soil much the same as sweet potatoes, groups of four to eight roots growing in a hill. The roots are 3 to 8 inches long, $1\frac{1}{2}$ to 3 inches in their greatest diameter, and for more than half their length taper toward the slender rootstock. The skins are rough and corky over the rootstock and basal portion, but thin and tender over the remainder. The interior is solid, brittle, a rich purple in color, and contains 23.17 per cent starch in the fresh material. When cooked these roots are of first-class texture, and rich, pleasing flavor. The roots of this variety, being small, keep well. Since they develop near the surface of the ground they can be dug without injuring them.

CONCLUSIONS.

The yam, which is nonresistant to frost, thrives well in Porto Rico, where the climatic conditions favor its growth. It is one of the most important root crops of the island and one of the lowest-priced foods. It is grown in family gardens in all parts of Porto Rico because it is well adapted to many soil types. Practically the entire crop is grown for home consumption.

Ridges of well-stirred soil and vegetable matter should be made sufficiently large when planting to enable the roots to make a normal growth above the water level in the soil and above the firm subsoil. The plants should be placed from 1 to 2 feet apart in these ridges, according to conditions peculiar to the root growth of each variety.

Either entire or parts of roots may be planted, although the crown or upper section was found to give the most satisfaction at the experiment station. Dipping in Bordeaux mixture was found to be an effective means of preventing decay of roots cut in pieces for seed.

Applications of fertilizers did not result in sufficient increase in the crop to warrant their recommendation. Where fertilizers are used none of the elements—nitrogen, phosphorus, or potash—should be omitted.

Tests in pruning the vines resulted in each case in a marked decrease in production. Yields were low also where supports had not been provided for the vines.

In harvesting yams care should be taken to avoid bruising the roots, because injured roots are usually attacked by disease and then decay.

Among the varieties commonly grown in Porto Rico, the one known as Guinea is the most desirable on account of its heavy yield, its high food value, and its pleasant flavor. The variety called Mapuey morado sells at a higher price than other yams, but its yield is usually low.

Among the lately introduced varieties recommended for general planting, the one known as Potato, which was introduced from Africa, and a variety of the species *Dioscorea alata* from New Guinea, produce heavy crops of roots having a high food value and palatable flavor.



